REMARKS

Applicants respectfully request reconsideration of the Office Action mailed August 8, 2002. Claims 1-3 and 6-8 remain presented for examination.

Applicants note with appreciation the courtesy extended by the Examiner in granting a telephone interview on September 17, 2002.

Objection to Claim 3

Claim 3 is objected to as being of improper dependent form for failing to further limit the subject matter of a previous claim. In the Office Action it is alleged that Claim 3 recites "wherein the final thickness is less than 20 angstroms," however, Claim 1 recites wherein the final thickness is less than 15 angstroms which is less than 20 angstroms.

Applicants respectfully disagree with the statement in the Office Action that Claim 1 recites wherein the final thickness is less than 15 angstroms. Claim 1 actually recites that the final oxynitride layer has "a final thickness," but does not limit the final thickness to a specific range. Claim 1 also recites that the final oxynitride layer has "an equivalent oxide thickness of less than 15 angstroms." The "final thickness" and the "equivalent oxide thickness" are distinct parameters. Equivalent oxide thickness (EOT), or electrical thickness of a given gate dielectric, is a relative measure of gate oxide thickness with respect to the actual physical thickness of a silicon dioxide layer having the same capacitance value as the given gate dielectric (p. 5, lines 17-20). Thus, Claim 1 specifies a range for equivalent oxide thickness of the final oxynitride layer, whereas Claim 3 specifies a range for the actual physical thickness of the final oxynitride layer.

Accordingly, Applicants respectfully submit that Claim 3 is not of improper dependent form because this claim further limits the final thickness of the final oxynitride layer. Applicants therefore request withdrawal of this objection.

Rejection of Claim 1 under 35 U.S.C. § 102(b) over Kraft *et al.*

Claim 1 is rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 6,136,654 to Kraft *et al.* Applicants respectfully traverse this rejection.

Claim 1 is directed to a method for forming a gate dielectric for an integrated circuit device. The method comprises the steps of: (a) forming an initial oxynitride layer upon a substrate material, the initial oxynitride layer having an initial physical thickness; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. It is a feature of the invention defined by Claim 1 that the final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms, *and* it is a further feature that the final oxynitride layer has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is not disclosed by Kraft *et al.* as detailed below.

The Kraft *et al.* patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). The oxygen-containing layer may be an oxide layer, an oxynitride layer, or other insulating layer (col. 3, lines 53-54).

Kraft *et al.* fail to disclose that after subjecting this oxygen-containing layer to a nitrogen-containing plasma, the layer has an equivalent oxide thickness of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. It is alleged in the Office Action that Kraft *et al.* teaches those limitations in Figure 7. Applicants respectfully disagree.

Figure 7 of the Kraft *et al.* patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). It is apparent from this disclosure that the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons.

First, the units of measure on the x-axis of the Figure 7 graph are "angstroms." Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, where depth is indicated in angstroms. Moreover, in the discussion of Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen (2.0×10^{15}/cm^2 or greater)

introduced into an oxide layer by plasma nitridation causes additional growth of the layer (p. 1, lines 17-19). Thus, if a 35 angstrom oxide film were nitrided under the conditions disclosed in the Kraft *et al.* patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be greater than 35 angstroms. Figure 7 shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 angstroms. The final thickness of the film therefore must be greater than 35 angstroms, which supports a conclusion that the initial oxide film thickness was 35 angstroms. (See Declaration of Mukesh Khare, submitted herewith, for further support of this conclusion.)

Figure 7 therefore clearly discloses data for an oxide film which had an initial thickness of 35 angstroms, and which was nitrided under conditions resulting in substantially complete formation of silicon nitride, resulting in a final thickness of over 50 angstroms. The equivalent oxide thickness of the final nitrided film in Figure 7 therefore can not be less than 15 angstroms. For this reason, Applicants therefore respectfully disagree with the statement in the Office Action that Figure 7 discloses a nitrided film having an equivalent oxide thickness of less than 15 angstroms.

During the telephone interview of September 17, it was discussed that Figure 7 fails to disclose a nitrided film having an equivalent oxide thickness of less than 15 angstroms. However, the Examiner further alleged that Figure 8 shows a nitrided film having this thickness. Applicants again disagree with this characterization of Figure 8 for the following reasons.

Like Figure 7, Figure 8 is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 8 illustrates data taken from a time of flight SIMS analysis of "a 7 oxide film" nitrided under specified conditions (col. 5, lines 54-56). It is apparent from this disclosure that the phrase "a 7 oxide film" was intended to mean "a 70 angstrom oxide film" for the following reasons.

First, the units of measure for the initial thickness of the oxide film must be angstroms for the same reasons discussed above with respect to Figure 7. The units of measure on the x-axis of the Figure 8 graph are angstroms. Second, it is clear that the initial thickness of the oxide film must have been 70 angstroms rather than 7 angstroms for several reasons. Kraft *et al.* disclose that the initial oxide-containing layer is preferably "a 10 to 150 [angstrom] thick"

layer (col. 3, line 52). A 70 angstrom oxide film falls within this range whereas a 7 angstrom oxide film does not. More importantly, however, Figure 8 indicates that the nitrogen and oxygen concentrations in the nitrided film were measured to a depth of 90 angstroms. While it is true that an oxide film subjected to nitridation would be expected to grow in thickness, one skilled in the art would not expect a 7 angstrom oxide film to grow to a final thickness of approximately 90 angstroms under the nitridation conditions disclosed by Kraft *et al.* On the other hand, one skilled in the art would expect a 70 angstrom oxide film to grow to a final thickness of approximately 90 angstroms under those nitridation conditions. (See Declaration of Mukesh Khare, submitted herewith, for further support of the conclusion that the initial oxide film thickness was 70 angstroms.)

Figure 8 therefore discloses data for an oxide film which had an initial thickness of 70 angstroms, and which following nitridation had a final thickness of about 90 angstroms. The equivalent oxide thickness of the final nitrided film in Figure 8 therefore can not be less than 15 angstroms. For this reason, Applicants therefore respectfully disagree with the statement in the Office Action that Figure 8 discloses a nitrided film having an equivalent oxide thickness of less than 15 angstroms.

It was also alleged during the telephone interview of September 17 that although the concentration of nitrogen in the film is not shown in Figure 8, the same nitrogen concentration would be expected in the Figure 8 film as that obtained in the Figure 7 film because the nitridation processes used for Figures 7 and 8 are similar. However, Applicants respectfully submit that neither the Figure 7 nor the Figure 8 nitridation processes would have resulted in a final oxynitride film having an equivalent oxide thickness of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2.

Initially, it is important to note that the process of the present invention begins with forming a heavily nitrided initial oxynitride layer, and concludes with subjecting this initial layer to a light nitridation in order to minimize growth of the layer. The initial oxynitride layer may be formed by, *e.g.*, rapid thermal nitric oxide (RTNO) or nitrogen ion implantation and rapid thermal oxidation. (See Declaration of Mukesh Khare, submitted herewith, for detail regarding the typical process conditions used for formation of the initial oxynitride layer.) Kraft *et al.* fail to

disclose any process conditions used to form their initial oxide-containing layer. Indeed, Kraft *et al.* teach only that the initial layer should be an oxide-containing layer, preferably an oxide layer.

More importantly, however, the nitridation conditions disclosed by Kraft *et al.* indicate that their oxide-containing film is subjected to a heavy nitridation, which would cause significant growth of the film. (See Declaration of Mukesh Khare, submitted herewith, for a comparison of the nitridation process conditions used by Kraft *et al.* and typical process conditions used in the method of the present invention.) Therefore, even if a high nitrogen concentration could be expected in the Figure 8 film, one skilled in the art would not expect such a high nitrogen concentration *in combination with* an equivalent oxide thickness of less than 15 angstroms, in view of the heavy nitridation process conditions used by Kraft *et al.*

Accordingly, Applicants respectfully submit that Claim 1 is not anticipated by Kraft *et al.*, and therefore request withdrawal of this rejection.

<u>Rejection of Claims 2-3 under 35 U.S.C. § 103(a) over Kraft *et al.*</u>

Claims 2-3 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft *et al.* Applicants respectfully traverse this rejection.

Claims 2 and 3 each depend from Claim 1. As discussed previously, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms, *and* it is a further feature that the final oxynitride layer has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft *et al.*

As discussed above, the Kraft *et al.* patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft *et al.* disclose that the oxygen-containing layer is "preferably either an oxide layer, an oxynitride layer, or other insulating layer" and more preferably an oxide layer (col. 3, lines 53-56). In every embodiment of Kraft *et al.*, an oxide layer is disclosed as the initial layer. Thus, Kraft *et al.* teach

that an oxide layer is more preferable than an oxynitride layer as the initial layer, and therefore *teach away* from using an oxynitride layer as the initial layer.

Moreover, Kraft *et al.* fail to disclose or even suggest that the final layer, after being subjected to a nitrogen-containing plasma, has an equivalent oxide thickness (EOT) of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. It is well known in the art that when an oxide-containing layer is subjected to a nitrogen-containing plasma, as taught by Kraft *et al.*, such that the final gate dielectric has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2, the resulting gate dielectric will have an EOT of greater than 15 angstroms. To achieve an EOT of less than 15 angstroms, after subjecting an oxide-containing layer to a nitrogen-containing plasma using methods known in the art, the final gate dielectric will have a much lower nitrogen concentration. Prior to the present invention, an oxynitride gate dielectric having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2 had not been achieved in the art.

Applicants have surprisingly discovered that when the initial layer is a heavily nitrided oxynitride layer, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric. Kraft *et al.* fail to recognize the superiority of using such an oxynitride layer as the initial layer, and therefore fail to suggest that the final oxynitride layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Moreover, by teaching that it is more preferred to use oxide as the initial layer rather than oxynitride, Kraft *et al.* are actually teaching away from achieving the above EOT and nitrogen concentration in the final layer.

For this reason, Applicants respectfully submit that Claim 1 is patentable over Kraft *et al.* Claims 2 and 3, which include all the limitations of Claim 1, are also patentable over Kraft *et al.* Applicants therefore request withdrawal of this rejection.

<u>Rejection of Claims 6 and 8 under 35 U.S.C. § 103(a) over Kraft *et al.* in view of Ito *et al.*</u>

Claims 6 and 8 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito *et al.* Applicants respectfully traverse this rejection.

Claims 6 and 8 each depend from Claim 1. As discussed above, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has an EOT of less than 15 angstroms, *and* it is a further feature that the final oxynitride layer has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft *et al.* in view of Ito *et al.*

Kraft *et al.* fail to disclose, and actually *teach away* from, a method wherein the final layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Ito *et al.* fail to remedy the deficiencies of Kraft *et al.* in this regard.

The Ito *et al.* patent is directed to a process for producing an oxynitride insulative film. The insulative film is formed by nitridation of an oxide film under a nitridation atmosphere containing nitrogen atoms (col. 4, lines 46-49). In all embodiments of Ito *et al.*, the initial layer is an oxide. Ito *et al.* fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, and fail to disclose or suggest a final insulative film having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Ito *et al.* therefore fail to provide any motivation to modify the teaching of Kraft *et al.* in this regard.

Accordingly, Applicants respectfully submit that Claims 6 and 8, which include all of the limitations of Claim 1, are patentable over Kraft *et al.* in view of Ito *et al.* Applicants therefore respectfully request withdrawal of this rejection.

Claim 8 is patentable over Kraft *et al.* in view of Ito *et al.* for the following additional reason. It is a feature of the invention defined by Claim 8 that the final oxynitride layer has a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer. Applicants respectfully submit that this feature is also neither disclosed nor suggested by Kraft *et al.* in view of Ito *et al.*

Kraft *et al.* fail to disclose or suggest anything about the effective electron mobility of their final layer with respect to their initial oxide layer. Since Kraft *et al.* fail to disclose or suggest that the final oxynitride layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2, Kraft *et al.* also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer.

Ito *et al.* fail to remedy the deficiencies of the Kraft *et al.* disclosure in this regard. Since Ito *et al.* fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, Ito *et al.* therefore also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer.

For this additional reason, Applicants respectfully submit that Claim 8 is patentable over Kraft *et al.* in view of Ito *et al.*, and therefore request withdrawal of this rejection.

<u>Rejection of Claim 7 under 35 U.S.C. § 103(a) over Kraft *et al.* in view of Gousev *et al.*</u>

Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft *et al.* in view of Gousev *et al.*, "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22. Applicants respectfully traverse this rejection.

Claim 7 depends from Claim 1. As discussed above, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has an EOT of less than 15 angstroms, *and* it is a further feature that the final oxynitride layer has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft *et al.* in view of Gousev *et al.*

Kraft *et al.* fail to disclose, and actually *teach away* from, a method wherein the final layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Gousev *et al.* fail to remedy the deficiencies of Kraft *et al.* in this regard.

The Gousev *et al.* paper is directed to methods of forming and characterizing "ultrathin nitrided silicon oxide films." The title of this paper reveals that all oxynitride films discussed therein are formed by nitriding oxide films. In other words, the initial layer in all embodiments is an oxide layer. Gousev *et al.* fail to disclose or even suggest that the initial layer should be an oxynitride layer. Moreover, Gousev *et al.* fail to disclose or suggest a final oxynitride layer having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Thus, Gousev *et al.* provide no motivation to modify the teaching of Kraft *et al.* in this regard.

Accordingly, Applicants respectfully submit that Claim 7, which includes all of the limitations of Claim 1, is patentable over Kraft *et al.* in view of Gousev *et al.* Applicants therefore respectfully request withdrawal of this rejection.

No fee is believed to be due for the submission of this Amendment. However, if any fees are required, please charge such fees to Deposit Account No. 09-0458.

Respectfully submitted,

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